ZED GLOBAL SYSTEM

ARTICULATION SOFTWARE MODULE

USER MANUAL - SUPPLEMENT

Ref. **ND0001760**

Issue **2.00**

Date **23rd December, 2010**

ZED Tunnel Guidance Ltd

Unit 1, Russell House, Molesey Road, Hersham,
Surrey, KT12 3PJ, UK.

Tel. +44 (0)1932 251440 **Fax. +44 (0)1932 244971**
Email: sales@zed-tg.co.uk **Website: www.zed-tg.co.uk**

Ó **ZED Tunnel Guidance Ltd 2010**
The information in this document is confidential and the property of ZED Tunnel Guidance Ltd. It is released on condition that it shall not be disclosed to a third party without the prior written consent of ZED Tunnel Guidance Ltd.

Contents

1. INTRODUCTION *5*

2. INSTALLATION *7*

2.1 Activating Articulation Mode *8*

3. CONFIGURATION *9*

3.1 Articulation Extensometer Settings *9*

3.2 Extensometer Data *11*

3.4.1 PLC via EtherNet/IP Link (ZEDOUT) 11
3.4.2 AB1734 POINT I/O Module via EtherNet/IP 13
3.4.3 RS232 Serial Link 15

3.5 ZEDIN Data Tag *16*

4. OPERATION *17*

4.1 Main View *17*

4.1.1 Mini View – Articulation 17
4.1.2 Mini View – Articulation Position 18
4.1.3 Mini View – Lead to Axis & Lookup to Axis 18
4.1.4 Mini View – Graphical Positions 20

4.2 Menu Pages *20*

4.2.1 Present Position Menu 20
4.2.2 Articulation Position Menu 21
4.2.3 Predicted Position Menu 21
4.2.4 Machine Params Menu 22

5. TROUBLESHOOTING *23*

5.1 PLC EtherNet/IP Link *23*

APPENDIX A – SETTING THE PDU IP ADDRESS *25*

1. INTRODUCTION

Normally for a double shielded or articulated Tunnel Boring Machine (TBM) the Combined Target Unit is mounted within the front shield. Occasionally this is not possible due to space restrictions and in this case these units have to be mounted in the rear shield. In order to measure the cutter position it is then necessary to measure the relative displacement between front and rear shields and it is for this purpose that the Articulation Software Module is used.

The articulation module receives data from extensometers or linear transducers within the hydraulic rams which are mounted around the circumference of the TBM between the front and rear shields. These can be read, either directly from a PLC using EtherNet/IP, from an Allen Bradley 1734 Ethernet/IP POINT I/O module, or via a serial RS232 link. From these ram extensions the elongation and angular deviation between front and rear shields may be determined and used in calculating the TBM's position.

2. INSTALLATION

For articulation support the ‘Articulation’ and ‘Head Ext.’ software modules need to be installed. Depending on how the extensometer values are being read either the ‘Ethernet/IP’ or ‘Serial’ module is also required. These are installed on the System Install menu page shown below.

Select the ‘Articulation’, ‘Head Ext.’ and, in this case, ‘Ethernet/IP’ (if not already installed) modules by clicking them. Now enter the keycode provided by ZED Tunnel Guidance for these modules. Then press the unlock button to install the modules. There should now be green ticks next to newly installed modules as shown below. **At this point the software should be shutdown and restart.**

2.1 Activating Articulation Mode

Once the necessary articulation modules have been installed it is possible to change the machine type to 'Articulated'. This is done on the System Connections menu page as shown below.

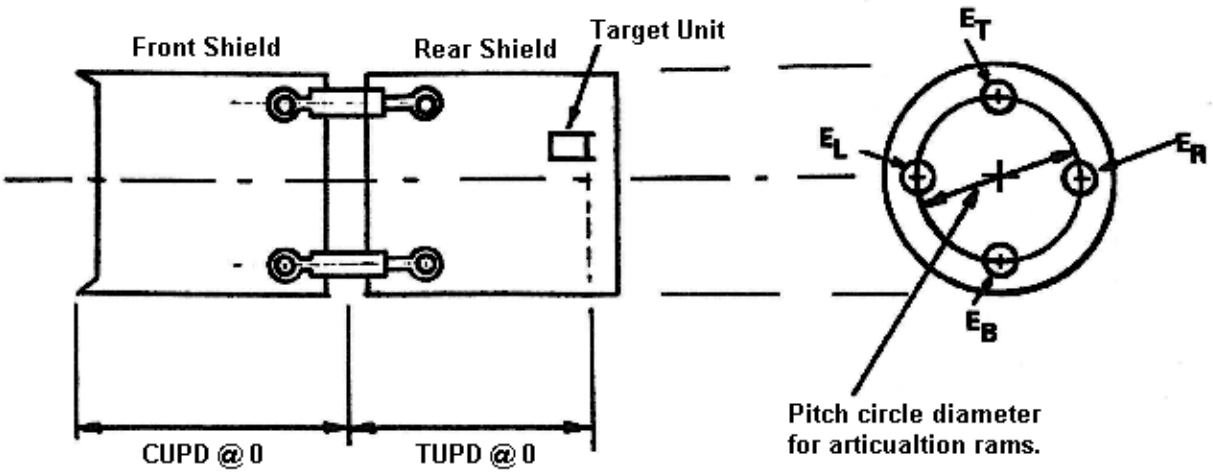
3. CONFIGURATION

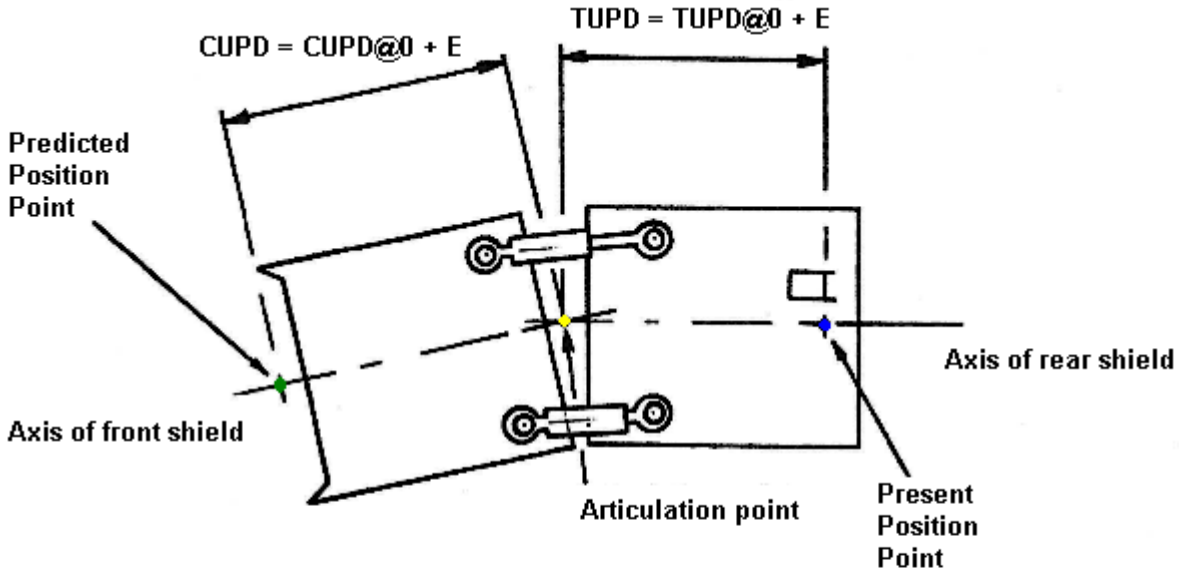
3.1 Articulation Extensometer Settings

The Articulation Setup menu page is used to define the positions of the Extensometers as well as some limit settings.

AR1,AR2,AR3,AR4	Articulation Extension Ram Label, Normally the number of the ram containing or nearest the Extensometer.
X	This is the X position (referenced from centre) of each articulation Extensometer. (Right is positive and Left is negative as viewed from the rear of the machine looking in the direction of advance).
Y	This is the Y position (referenced from centre) of each articulation Extensometer. (Up is positive and Down is negative as viewed from the rear of the machine looking in the direction of advance).
AE1,AE2,AE3,AE4	Articulation Extensometer value being received by the system.
Min Extension	The value entered here determines the Minimum Extension value the system will allow as a valid value.
Max Extension	The value entered here determines the Maximum Extension value the system will allow as a valid value.
TUPD @ 0	**T**arget **U**nit to **P**ivot **D**istance - The value entered here is the distance from the plane of the Target Unit Front Screen to the articulation pivot plane when the extensometers are at zero.
TUPD	The value displayed here is the value entered at TUPD @ 0 with the addition of the extensometer component values.
CUPD @ 0	**CU**tter to **P**ivot **D**istance - The value entered here is the distance from the articulation pivot plane to the desired predicted position of the cutter when the extensometers are at zero, .i.e. closed.
CUPD	The value displayed here is the value entered at CUPD @ 0 with the addition of the extensometer component values.
Interface	Determines how extensometer values are brought into the system.

Below are diagrammatic plan views of an articulated TBM in the closed position and in the open or articulated position.





$$2E = \frac{E_T + E_B + E_R + E_L}{4}$$

$$E = \frac{E_T + E_B + E_R + E_L}{8}$$

3.2 Extensometer Data

Extensometer data can be read by the system in various ways. Currently the values can be extracted directly from the TBM PLC or an Allen Bradley 1734 POINT IO module via an EtherNet/IP link.

3.4.1 PLC via EtherNet/IP Link (ZEDOUT)

For the system to extract values from a PLC various values need to be configured. This is done in the EtherNet/IP menu page.

PLC Type	ControlLogix / CompactLogix Specifies the type of PLC the system is connected to.
IP Address	This is the IP Address of the PLC.
PLC Slot#	For some PLCs the number of the slot in which the PLC is mounted in the chassis needs to be entered.
ZEDIN Tag	None / Descriptive name Shows the descriptive name of the current ZEDIN.tag file. A value of *None* means that this data export facility to the PLC is currently disabled.
	Apply New ZEDIN.tag Button. – This is used to import a new ZEDIN.tag file from an attached device. If a ZEDIN.tag file is found in the root folder of the attached device, it is imported and applied. The *ZEDIN Tag* field will update to show the new file description.

The default IP address for a PDU is 192.168.1.222 with a subnet mask of 255.255.255.0. It is important that the subnet portion of the IP address, in this case 192.168.1, is the same on the PDU and the PLC it is trying to communicate to. If the PDU IP address needs changing then please see *Appendix A – Setting the PDU IP Address*.

ZEDOUT Data Tag

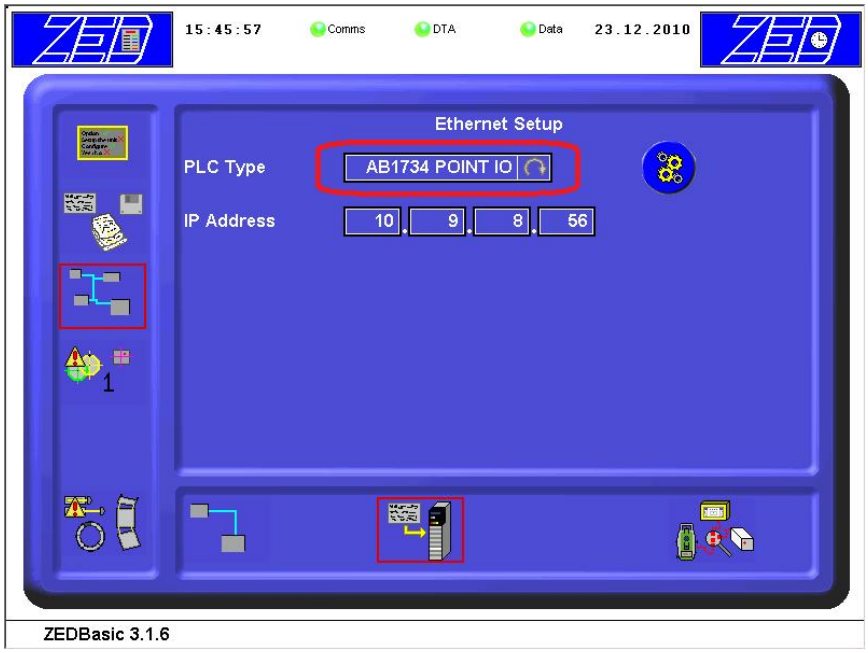
The values in the PLC are extracted by reading the ZEDOUT tag in the PLC's Data Tag Table. This tag needs to be created in the PLC as a User Defined Type (UDT) and its data members need to match the extensometer values expected by the ZEDGlobal system. Each data member should be a DINT and the order shown in the table below should be maintained, omitting any extensometers not present on the system.

Member Name	**Description**
BTE	Boom Travel *(if present)*
BSE	Boom Swing *(if present)*
BLE	Boom Lift *(if present)*
AE1	Front Hood Articulation Extensometer 1 – top right quadrant
AE2	Front Hood Articulation Extensometer 2 – bottom right quadrant
AE3	Front Hood Articulation Extensometer 3 – bottom left quadrant
AE4	Front Hood Articulation Extensometer 4 – top left quadrant
SE1	Shove Ram Extensometer 1 – top right quadrant *(if present)*
SE2	Shove Ram Extensometer 2 – bottom right quadrant *(if present)*
SE3	Shove Ram Extensometer 3 – bottom left quadrant *(if present)*
SE4	Shove Ram Extensometer 4 – top left quadrant *(if present)*
TE1	Tail-Skin Extensometer 1 – top right quadrant *(if present)*
TE2	Tail-Skin Extensometer 2 – bottom right quadrant *(if present)*
TE3	Tail-Skin Extensometer 3 – bottom left quadrant *(if present)*
TE4	Tail-Skin Extensometer 4 – top left quadrant *(if present)*

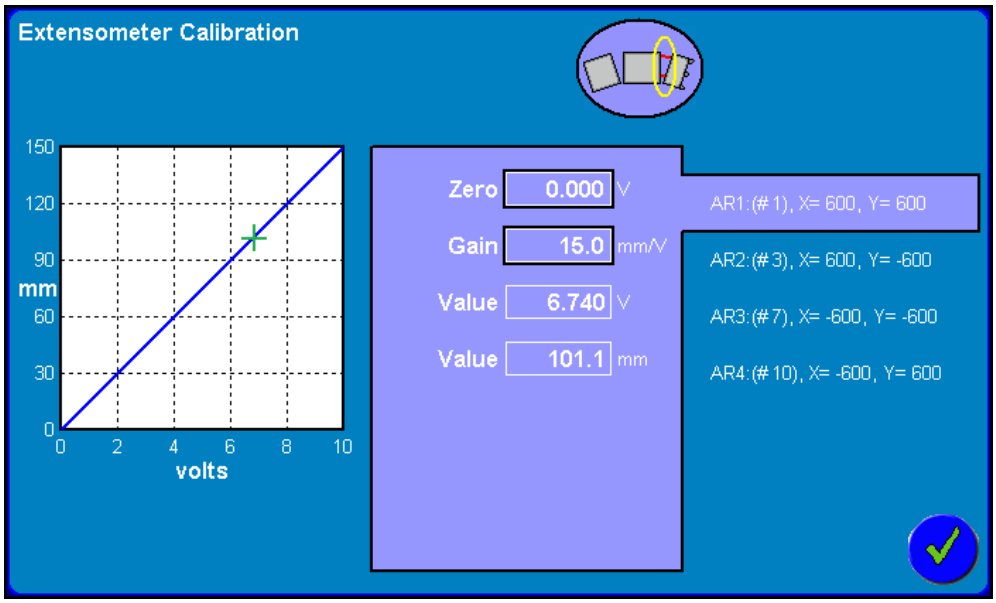
If the number of extensometer values transmitted to the ZEDGlobal system does not match the ZEDGlobal configuration the extensometer values will have a Data Format error indicated by the '^' symbol.

3.4.2 AB1734 POINT I/O Module via EtherNet/IP

If no direct link to a PLC is available then the ram extensometers can be connected to an Allen Bradley 1734 Ethernet/IP POINT I/O module. The supported types of extensometer outputs are 0-10VDC or 4-20mA. This mode is selected on the Ethernet Setup menu page as shown below.



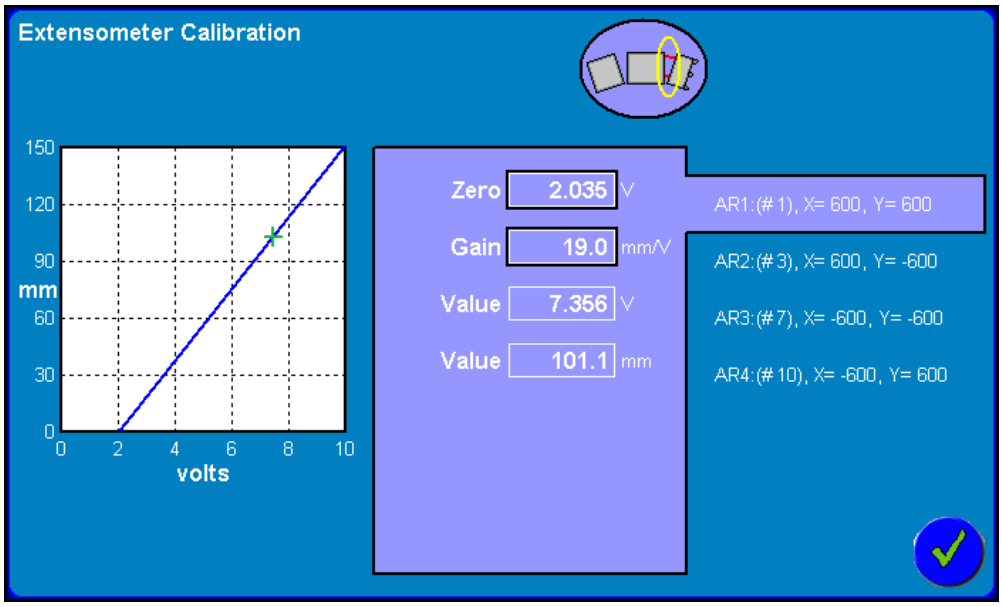
By selecting "AB1734 POINT IO" as the PLC type and specifying the IP address of the module it is possible to read the extensometer output. It is necessary to calibrate the conversion of the incoming voltage to an extension distance. This is done using the "Extensometer Calibration" dialog accessed by pressing the 'settings' button.



This dialog allows the calibration of all extensometers types. A symbol for each type (CutterHead, Shove, Tail-skin, and Boom) of extensometer installed will be shown. By clicking the symbol the corresponding group of extensometers are shown. By clicking the individual extensometer labels the settings for each one can be viewed and edited.

The two editable fields are “Zero” and “Gain”. The “Zero” value specifies at which voltage the extensometer is reading 0mm. This zero offset will move the start of the graph along the bottom X axis. The “Gain” value specifies the distance that each volt corresponds to. This will set the slope of the graph. The two values below show what the current voltage is and what distance this equates to using the current zero and gain parameters. These values are also shown on the graph as a green cross.

The maximum extension distance on the Y axis needs to be set for each extensometer type using the Ram Setup menu pages, see Section 3.1 for details on the Articulation Setup.

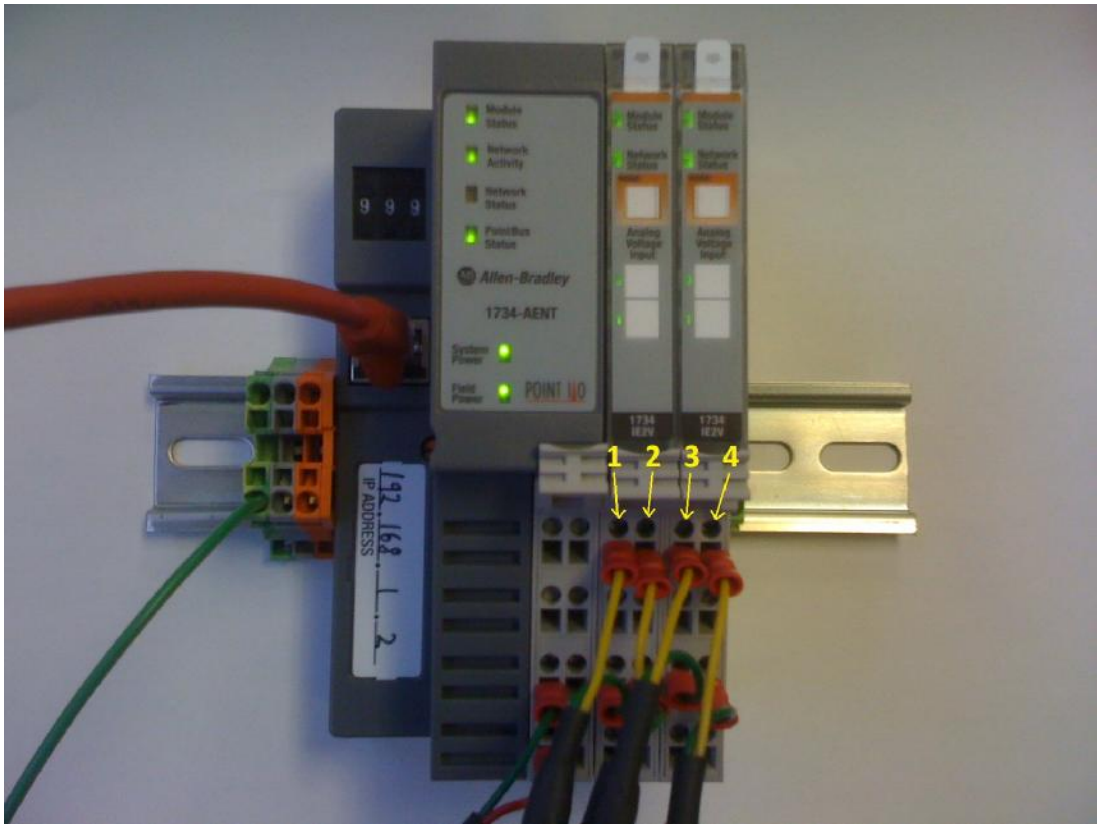


The example above shows how adjusting the zero value affects the graph. The best method of calibrating the extensometers is to fully retract the ram and then enter the voltage value shown as the zero offset. Then position the ram to a known distance, e.g. 1000mm, and adjust the gain until the distance value reads the correct distance.

For cutterhead articulation rams it may be difficult to stroke the rams in this way. In this case we recommend setting all rams to their middle positions and adjusting the zero and gain values such that the graph is balanced about the current middle position.

The extensometer outputs need to be wired into the appropriate IO module. The table below details the order in which they should be wired going from left to right in the module.

Name	**Description**
BTE	Boom Travel *(if present)*
BSE	Boom Swing *(if present)*
BLE	Boom Lift *(if present)*
AE1	Front Hood Articulation Extensometer 1 – top right quadrant
AE2	Front Hood Articulation Extensometer 2 – bottom right quadrant
AE3	Front Hood Articulation Extensometer 3 – bottom left quadrant
AE4	Front Hood Articulation Extensometer 4 – top left quadrant
SE1	Shove Ram Extensometer 1 – top right quadrant *(if present)*
SE2	Shove Ram Extensometer 2 – bottom right quadrant *(if present)*
SE3	Shove Ram Extensometer 3 – bottom left quadrant *(if present)*
SE4	Shove Ram Extensometer 4 – top left quadrant *(if present)*
TE1	Tail-Skin Extensometer 1 – top right quadrant *(if present)*
TE2	Tail-Skin Extensometer 2 – bottom right quadrant *(if present)*
TE3	Tail-Skin Extensometer 3 – bottom left quadrant *(if present)*
TE4	Tail-Skin Extensometer 4 – top left quadrant *(if present)*



The photo above shows a AB1734 module with 4 extensometers installed. In this case they are 4 cutterhead articulation extensometers. Therefore, using the table on the previous page they should be wired in the following order from left to right; AE1, AE2, AE3, AE4. These values correspond to the four quadrants used on the Articulation setup menu page.

After the extensometers have been wired and calibrated the general operation should be checked to ensure that they have been installed in the correct order. This is best done by placing the articulation into a known direction, e.g. up and right, and then checking that the calculated angles are as expected.

3.4.3 RS232 Serial Link

This mode is under development.

3.5 ZEDIN Data Tag

The ZEDIN Data Tag is used to export guidance data from the ZED system to a PLC. This feature is activated by importing a ZEDIN.tag file obtained from ZED Tunnel Guidance. This file specifies which data variables are to be exported and in which order they appear. The tag needs to be created in the PLC as a User Defined Type (UDT) and its data members need to match the file order. For each data value specified **two** DINTs need to be created in the tag. The first DINT is for the data value and the second is for any errors associated with this value.

The first DINT in the tag should be called HEAD and the last should be TAIL. These values will increase everytime new data is written to the tag and the tag data should only be used if the head value equals the tail value.

The table below shows an example ZEDIN tag for two values called XS and YS.

Member Name	Description
HEAD	DINT – Used for ensuring all data is synchronised.
XS_Value	DINT - Value of XS in mm or centi-feet depending on system setup.
XS_Error	DINT – The current error, if any, for XS.
YS_Value	DINT - Value of YS in mm or centi-feet depending on system setup.
YS_Error	DINT - The current error, if any, for YS.
TAIL	DINT – Used for ensuring all data is synchronised.

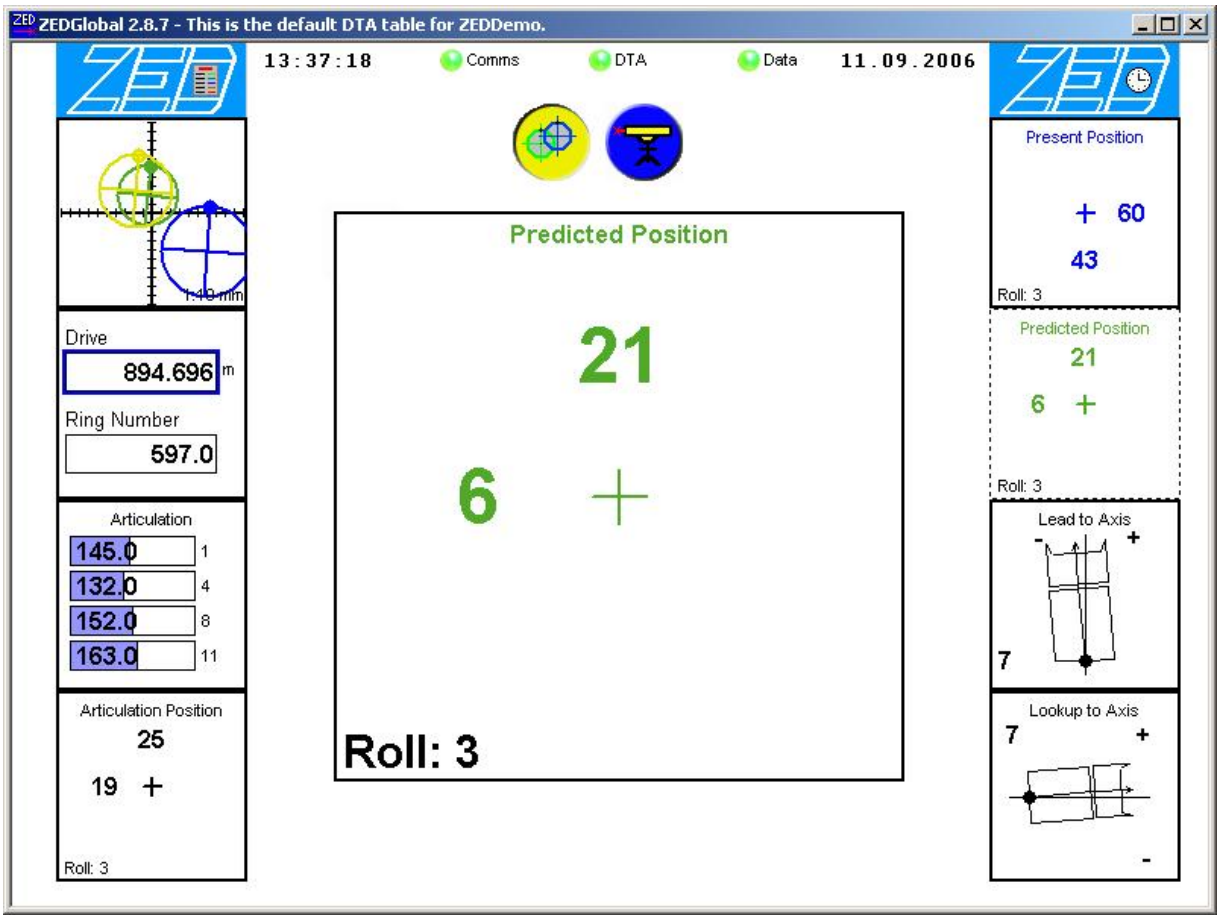
The table below shows the possible errors which can be associated with a value

Error Number	Error Type	Description
0	No Error	Data valid
1	Data Unavailable	Somewhere in the guidance system there is a communication problem and the data from that unit is not available. Therefore, the guidance data can not be calculated.
2	Light	There is a light error on the target or total station EDM. The guidance calculations can not be completed
3	Range	This data value has exceeded its allowable range, or a value required to calculate this value has exceeded its range.
4	Calculation	The guidance calculations could not be completed and this value was not calculated.
5	Transmission	A communication link at the ZED PDU unit is broken, it can't get the data it needs.
6	Data Format	Some data that the system is expecting is arriving in the wrong format. This could be to do with reading the ZEDOUT tag from the PLC or if the PDU has been incorrectly configured for the current target unit.
7	Data Value Not Found	The piece of data specified in the ZEDIN.tag file could not be found in the system. Please contact ZED Tunnel Guidance.
8	Undefined	An unexpected error has occurred on this data value. Please contact ZED Tunnel Guidance.

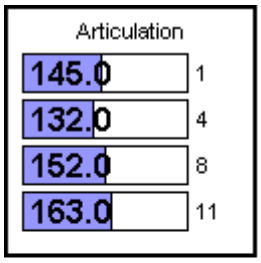
4. OPERATION

4.1 Main View

When running in articulated machine mode the main view is as shown below:

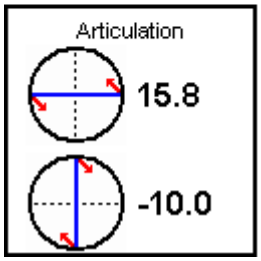


4.1.1 Mini View – Articulation

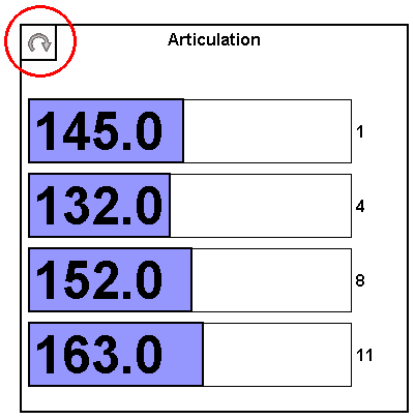


The articulation view displays the articulation extensometer values or articulation angles.

The incoming extensometer value is displayed for each ram along with the ram label. The shaded area represents the current extension where no shading indicates 0 (closed) and fully shaded indicates max extension.

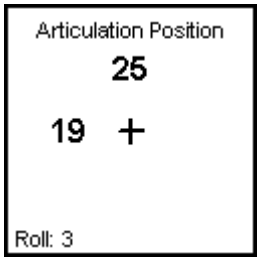


In this mode the horizontal and vertical articulation angle is shown.



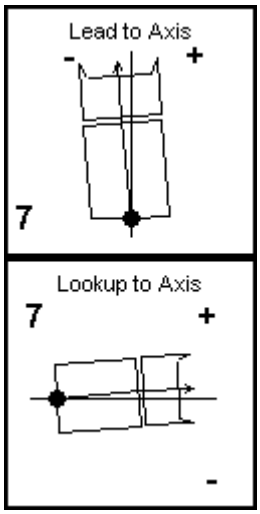
To change between the display modes the articulation mini view needs to be selected into the middle by clicking it. As shown on the left a toggle mode button appears in the top left corner of the view. By clicking this it is possible to cycle between the available mode. ZEDGlobal will remember the last selected mode.

4.1.2 Mini View – Articulation Position



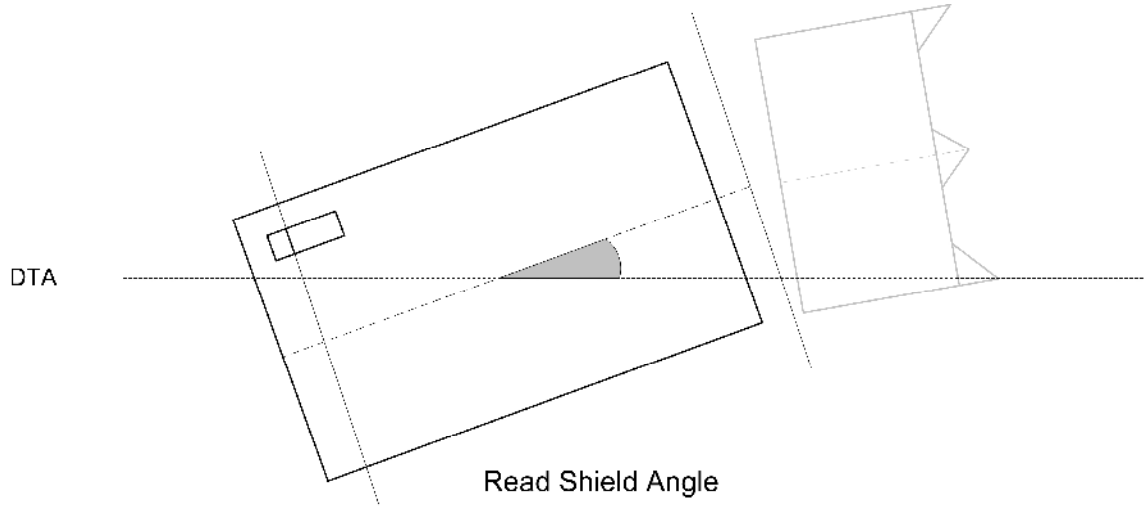
This view shows the position of the articulation pivot point relative to the DTA.

4.1.3 Mini View – Lead to Axis & Lookup to Axis

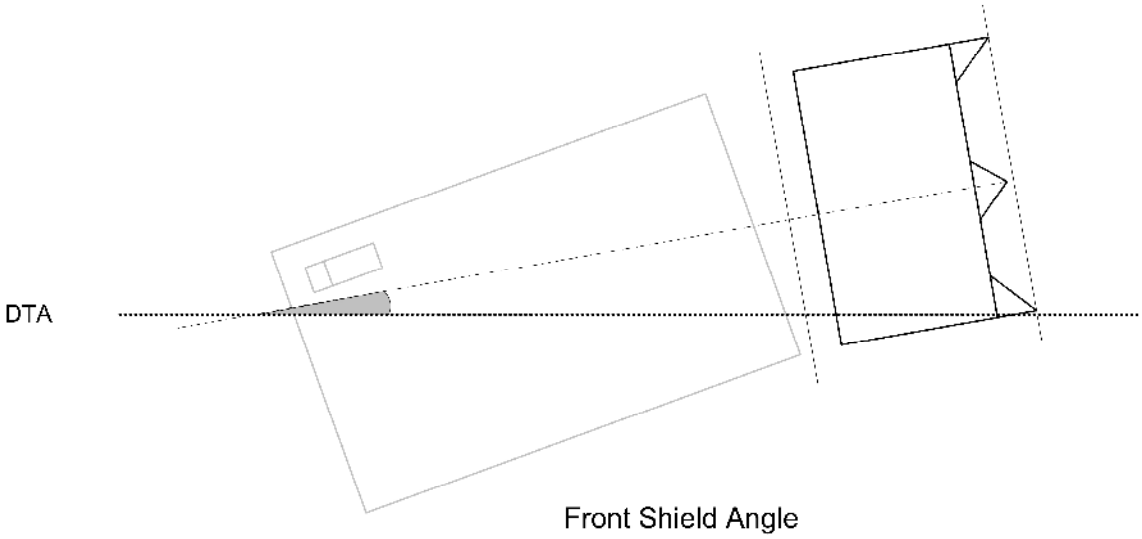


In an articulated machine each shield has a different lead and lookup to the DTA depending on the articulation. Using these two values a combined lead and lookup to the DTA can be calculated. This combined value is the one displayed by these mini views. The diagram below illustrates these three sets of values.

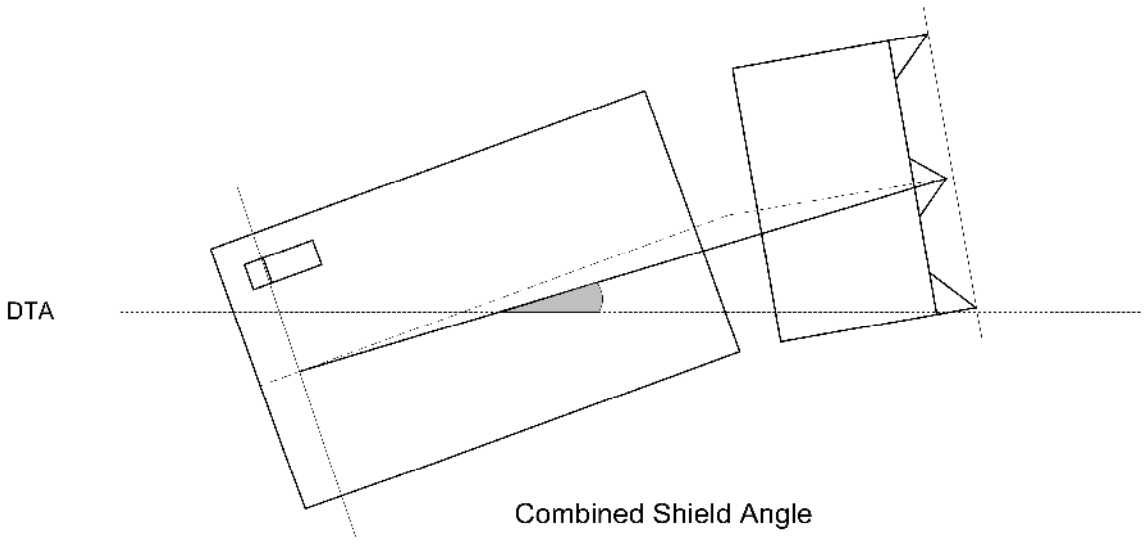
Note: The drawing of the front and rear shield only indicates that articulation mode is active and is not an indication of the current attitude of the machine.



Read Shield Angle

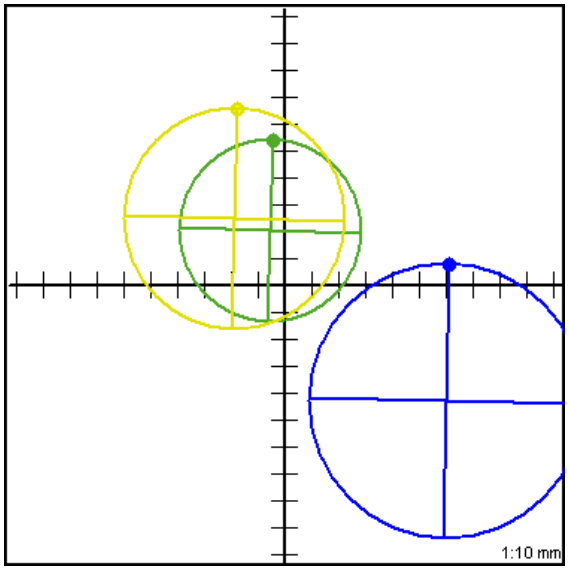


Front Shield Angle



Combined Shield Angle

4.1.4 Mini View – Graphical Positions



This view shows the present position (blue), articulated position (yellow) and predicted position (green) relative to the DTA. The DTA is the centre of the cross and the view is drawn from the rear of the machine looking forwards in direction of advance. The scale in the bottom right indicates what each tick mark on the cross represents, in this case 10mm.

In this example you can see that the present position is to the right and below the DTA. However, the rear shield is angled in such a way that the articulated position is above and to the left of the DTA. The articulation of the front shield then takes the predicted position slightly to the left and above the DTA.

If the machine was on the DTA and at the same angle all three circles would be concentric about the middle of the cross.

4.2 Menu Pages

When running in articulated mode some of the menu pages change their behaviour slightly.

4.2.1 Present Position Menu

Present Position	The X and Y offset of the TBM centre from the DTA at the present position plane. This is the plane of the front screen in the target unit.
Global Machine Position	Global position of the TBM centre at the present position plane in North, East and Level.
Lead to Axis	Lead angle, to the DTA, of the rear shield where the target is mounted.
Lookup to Axis	Lookup angle, to the DTA, of the rear shield where the target is mounted.

4.2.2 Articulation Position Menu

Articulated Position	The X and Y offset of the TBM centre from the DTA at the articulation plane. This is the plane mid-way between the front and rear shields.
Global Machine Position	Global position of the articulation pivot point between the two shields, specified in North, East and Level.
Lead to Axis	Lead angle, to the DTA, of the front shield.
Lookup to Axis	Lookup angle, to the DTA, of the front shield.

4.2.3 Predicted Position Menu

Predicted Position	The X and Y offset of the TBM centre from the DTA at the prediction plane. This plane is a distance of CUPD + extensions ahead of the articulation point, normally set to the plane of the cutter face.
Global Machine Position	Global position of the predicted position in North, East and Level.
Lead to Axis	Lead angle, to the DTA, of the rear and front shield combined.
Lookup to Axis	Lookup angle, to the DTA, of the rear and front shield combined.

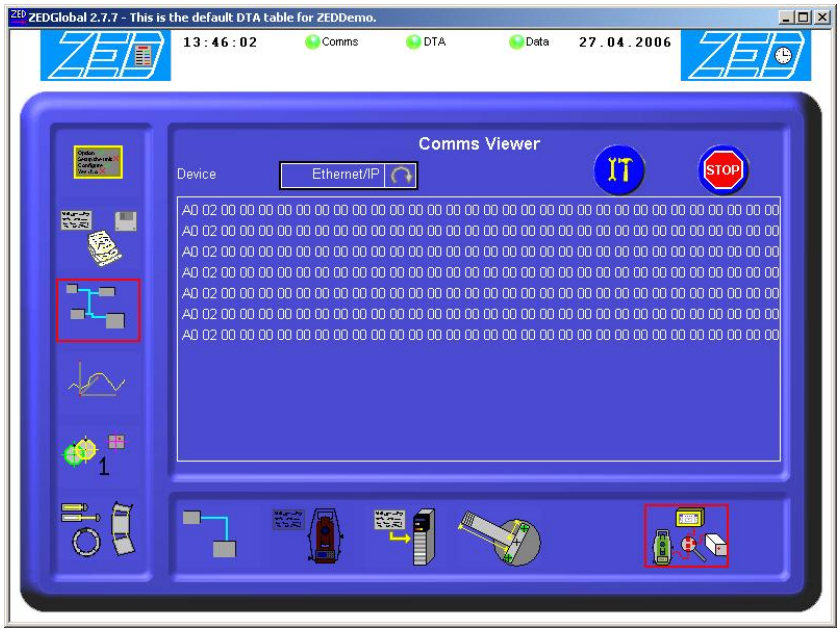
4.2.4 Machine Params Menu

As shown above the prediction distance is a calculated value in an articulated system. It is the sum of the current values of TUPD and CUPD and will vary as the articulation rams change.

5. TROUBLESHOOTING

5.1 PLC EtherNet/IP Link

The Comms Viewer menu page can be used to help find any problems associated with the EtherNet/IP link.



Toggle the device until it reads ‘Ethernet/IP’. If the system is working properly many values should be scrolling down the screen. Each line should start with “A0 02” followed by the extensometer values.

If a line starts with “EIP Error:” followed by a number, as shown below, then look up that number in the EIP error table.

EIP Error Table:

EIP Error	Description
8	The PLC did not recognize the service (0x4C – Read tag) it was asked to perform.
13	Unable to find an Ethernet/IP target at the specified IP address. Verify IP address and ensure it has been entered correctly.
14	IP address found, but network path doesn't complete. Check the correct PLC type and slot number is configured in the menu.
20	Unknown attribute specified. Check that the ZEDOUT tag has been created in the PLC's data tag table.
10001	Failed to send unconnected message. Internal error.
10002	Incorrect number of extensometer values returned from the PLC. Check that the number of entries in the ZEDOUT data tag match the number of extensometers expected by the ZEDGlobal software. This will result in a data format error, '^', on the extensometer values.
10003	Incorrect data type. Check that the PLC data tag has been created as a User Defined Type (UDT).

For further advice or if the error is not listed in the table, contact ZED Tunnel Guidance.

If there is nothing displayed in the comms window when the 'Ethernet/IP' device is selected then the network connection on the PDU is not working. Ensure the IP addresses for the PLC and PDU are compatible. See Appendix A below for information on how to change the PDU IP address.

APPENDIX A – SETTING THE PDU IP ADDRESS

The IP address of the PDU needs to have the same subnet as the PLC it is trying to talk to. Normally the subnet mask is 255.255.255.0 which means the first three numbers of the IP address needs to be the same. For example if the PLC's address is **192.168.0**.60 then the PDU needs to have an IP address of **192.168.0**.xxx, where xxx is a unique number on the local network.

The default IP address for a PDU is 192.168.1.222.

To set the IP address you will need a USB keyboard plugged into the USB port on the side of the PDU (top connector).

1. Close ZEDGlobal.
2. Run *Explorer* from the start menu. To do this move the mouse cursor down to the bottom of the screen to reveal the taskbar. Press the Start menu button which should contain the explorer item.
3. Open *Control Panel* from within *My Computer*.
4. Open *Network Connections*.
5. Select *Local Area Connection*. Now open *Properties* from the *File* menu.
6. Select *Internet Protocol (TCP/IP)* and press the *Properties* button.
7. Select *Use the Following IP Address* option, if not already selected.
8. Enter your IP address.
9. Enter your subnet mask.
10. Press *OK*.
11. Press *Close* on the network connections dialog.
12. Run ZEDGlobal.